MOUNT GRAHAM RED SQUIRREL JUVENILE DISPERSAL TELEMETRY STUDY

Melissa E. Kreighbaum, Nongame Wildlife Specialist
William E. Van Pelt, Nongame Mammals Program Manager

Nongame Branch, Wildlife Management Division
Arizona Game and Fish Department

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INTRODUCTION

Red squirrels (*Tamiasciurus hudsonicus*) are found in subalpine conifer forests consisting of spruce, fir, and various pine species (Brown 1984). In North America, this habitat stretches from boreal forests in Alaska and Canada south to the coniferous forests of Arizona and New Mexico, and in the east from North Dakota to the Atlantic and south to Georgia (Chapman and Feldhamer 1982). The Mount Graham red squirrel (*T. h. grahamensis*) (MGRS) is a subspecies found only in the Pinaleno Mountains of southeastern Arizona, the southernmost location for the species (Brown 1984, Hoffmeister 1986).

The Mount Graham red squirrel was uncommon to rare in the 1950s, and by the 1960s was believed to be extinct (Hoffmeister 1986). In 1972, the subspecies was rediscovered at higher elevations on Mount Graham (Hoffmeister 1986, Spicer et al. 1985), the highest peak in the Pinaleno Mountains. Due to low population estimates and habitat degradation, the MGRS was listed as endangered by the U.S. Fish and Wildlife Service on June 3, 1987 (52 FR 20994-20999). It is being considered for inclusion on the Arizona Game and Fish Department's (AGFD) list of *Wildlife of Special Concern in Arizona* (AGFD in prep.), which will replace the AGFD's *Threatened Native Wildlife in Arizona* (AGFD 1988). These lists provide guidance to state and federal agencies and the public on the AGFD's priorities for wildlife management, but do not afford specific legal or regulatory protection.

To survive the winter, all red squirrels must have a midden (Larsen and Boutin 1994), which is a pile of cone scales in which unopened cones are stored. The only known reasons for home range abandonment are: 1) males leave their home ranges to seek females during the breeding season; 2) juveniles may disperse from natal middens to establish their own home range; 3) mother squirrels may bequeath the natal home range to their offspring; and 4) either sex or any age group may leave to search for a home range with a better food supply (Smith 1968).

Adult female red squirrels may occasionally share their home range with their young (Boutin and Schweiger 1988, Larsen and Boutin 1994, Price et al. 1986, Wells 1987). Philopatry occurs when the mother bequeaths part or all of her home range to her offspring (Brown 1984, Larsen and Boutin 1994, Price et al. 1986, Wauters and Dhondt 1993). Juvenile dispersal occurs when the mother forces her offspring to find their own territories (Smith 1968). It is not known how far dispersing young or adult female MGRSs go to establish a home range.

The objectives of this study were: 1) to define movement patterns (dispersal and home range) among radio collared adult female MGRSs with juveniles; and 2) investigate the possible occurrence of adult females relinquishing the natal midden to juveniles. Secondary objectives were to investigate

alternate trapping methods and to observe survival rates of radio-collared MGRSs.

This report summarizes trapping and radio collaring results from September 1, 1994 to October 12, 1995, and telemetry monitoring from September 7, 1994 through February 9, 1996.

METHODS

Potential MGRS trap sites occurred in the Bible Camp, Columbine, Grant Hill, and Swift Trail areas. Trap locations were selected according to the following criteria:

1) Presence of a lactating female with young approximately nine to 11 weeks old but still in the midden area.

2) An area containing a dense aggregation of red squirrels and an area with a sparse aggregation of squirrels.

3) Ease of access to expedite data collection during the winter when access may be limited by deep snow conditions.

In August 1994, members of The University of Arizona's Mount Graham Red Squirrel Monitoring Program (RSMP) assisted with locating female MGRSs with emerging juveniles. Middens selected for trapping were within 200 m of the Swift Trail road, which allowed for easy access during the winter. In September 1994, trapping was initiated while juveniles were still present at their natal middens.

In May 1995, surveys for female MGRSs were conducted in the Grant Hill, Bible Camp, and Swift Trail areas. Grant Hill contained a sparse aggregation of squirrels, whereas the Bible Camp and Swift Trail areas held dense aggregations (pers. obs.). Females were monitored for the first signs of lactation. This information was used to help estimate when juveniles would reach the recommended 64 days of age for trapping and collaring (Larsen and Boutin 1994). Trapping commenced in August 1995.

Squirrels were trapped with Tomahawk® live traps (42 x 14.5 x 14 cm) placed within 12 m of target middens and baited with peanut butter, peanuts, cones and/or mushrooms. Traps were opened during daylight hours and constantly monitored by project personnel. For MGRS safety, project personnel gained handling and immobilizing experience by practicing on red squirrels (*T. h. mogollonensis*) in the Flagstaff area prior to trapping MGRSs.

When a MGRS was captured, its sex and age were determined. Only adult females or juveniles were retained for this study. Burlap or a coat was placed over the trap to calm the squirrel while preparations were made for immobilization. Individuals were weighed to calculate the correct dosage of the immobilizing drug Telazol® at a concentration of 100 mg/cc. Stiff padding was used to

restrain the squirrel at one end of the trap to ensure safe, unhampered injection of the immobilizing drug in the left or right hind quarters. Once the squirrel was immobilized, Duolube® was used to retain eye moisture. Information collected at each capture site included rectal temperature and standard body measurements (total length, tail length, right hind foot, right ear).

Anesthetized squirrels were collared with a Telonics® radio collar, consisting of an epoxied CHP 2P transmitter and a flexible TA-5ULT external wire antenna mounted on a "ladder" cable tie. Estimated battery life for this type of collar, with a weight of less than seven grams, is six to eight months. It was attached tight enough to prevent slipping off, but loose enough so that normal activities were not hampered.

Squirrels were placed in a wooden box (60 x 45 x 45 cm) to recover from the effects of the tranquilizer. Food and moisture were readily available in the form of cones and mushrooms, and squirrels were monitored closely. When the squirrels appeared to recover from the effects of the tranquilizer, they were released at the place of capture and observed for up to one hour to ensure that each individual had recovered its motor capabilities.

Whenever possible, telemetry locations were confirmed with visual observation of the collared squirrel. All locations were taken with Global Positioning System (GPS) instruments, except those within five meters of the resident midden and other repeated locations within the squirrel's home range, such as feeding stations. Accuracy was within five meters and locations were differentially corrected.

As a possible alternative to using Tomahawk live traps, nest box traps (20 x 9.25 x 7 cm) were constructed according to Teaford (1986), with the addition of a metal door that could slide across the opening, effectively trapping the squirrel. Four nest box traps were tested near Mormon Mountain on the Coconino National Forest from February 23 to May 18, 1995. Four nest box traps were then placed in the Pinaleno Mountains on June 15, 1995 at middens with females; three in the Bible Camp area and one in the Grant Hill area.

RESULTS

CAPTURE AND COLLARING

From September 1 to October 19, 1994, 802 trap hours were expended to trap seven squirrels: six adult females and one juvenile male. One of the adult females was the mother of the juvenile male. From August 8 to October 12, 1995, 2285 trap hours were expended to trap eight squirrels: two adult females and six juveniles; three males and three females (Table 1). Three of the juveniles (two females and one male) were suspected siblings based on behavior, weight, and location.

Even though few squirrels were trapped and radio collared, trapping success was considerably better than others have experienced on Mount Graham (Krausman and Smith 1990; P.J. Young pers.

comm.). A mean of 193 trap hours was required for each squirrel for this study, while Krausman and Smith (1990) expended as many as 3711 trap hours for each squirrel captured. Higher capture rates may be due to close observation of squirrels and trapping in areas with high squirrel activity.

NEST BOXES

In 1995, nest box traps were constructed, mounted, and tested near Flagstaff as an alternative means of capturing red squirrels. Other studies (Barkalow and Soots 1965, Burger 1969) showed some squirrels will use artificial dens. During the test period it appeared that the red squirrels were removing the nest material and food that were placed in the nest boxes. One squirrel was observed emerging from a nest box. However, nest boxes placed near middens on Mount Graham were not used by MGRSs during this study.

HOME RANGES

The mean home range for all telemetered squirrels was 0.9214 ha. Adult and juvenile means were 1.1465 ha and 0.1963 ha, respectively. Home ranges varied in size from 0.0339 ha (Fig. 1) to 1.981 ha (Fig. 2).

Squirrel number 2, which was collared on September 2, 1994, expanded its home range from 0.520 ha to 1.981 ha (Fig. 2) after neighboring residents, numbers 5 (Fig. 3) and 6 (Fig. 4), were preyed upon. Evidence for this expansion was later confirmed when squirrel number 2 was observed eating cones at the middens and was not challenged by a new resident.

An unoccupied midden, CO 100, was in the home range of four different squirrels (Figs. 2, 3, 4 and 5). Three of these squirrels were observed at this midden eating cones and exploring. However, each squirrel defended a different home range and no squirrel was observed defending this common midden. Squirrel number 9 (Fig. 6) repeatedly visited the area of a disappeared midden, eating cones in a nearby tree.

[1]A = Adult J = Juvenile

Table 1. Summary of trapping and monitoring of radio-telemetry collared *Tamiasciurus hudsonicus grahamensis* in the Pinaleno Mountains of southeastern Arizona.

DATE COLLARED/ LOCATION	AGE[1]/SEX ID	HOME RANGE SIZE (HECTARES)	# OF LOCATIONS	COLLAR RECOVERY LOCATION	RETRIEVAL DATE OR LAST SIGNAL	END RESULTS
09/02/94 CO 60	A/_ #1	0.0339	27	CO 122	09/30/94	Avian predation
09/02/94 CO 119	A/_ #2	initial= 0.520 final= 1.981	55	Not recovered	04/27/95	Suspected death
09/04/94 CO 114	A/_ #3	1.725	54	Not recovered	03/02/95	End of Study
09/15/94 CO 89	J/_ #4	0.2622	11	ST 16	09/23/94	Avian predation
10/04/94 CO 89	A/_ #5	0.7741	12	ST 26	10/20/94	Avian predation
10/05/94 CO 118	A/_ #6	1.857	15	Between CO 118 & CO 114	10/27/94	Avian predation
10/18/94 CO 60	A/_ #7	0.3915	20	Near CO 69	04/26/95	Cause unknown
08/23/95 ST 03	J/_ #8	0.2168	36	Not recovered	01/12/96	Collar stopped working
08/26/95 BC 41	A/_ #9	1.263	31	BC 41	12/06/95	Collar chewed off
09/13/95 GH 07	J/_ #10	--	--	Not collared	--	Died from handling
09/20/95 09/24/95 BC 51	A/_ #11	--	2	BC 51	09/21/95 09/26/95	Collars chewed off
10/06/95 GH 07	J/_ #12	--	3	GH 07	10/07/95	Predation?
10/06/95 GH 07	J/_ #13	0.1098	17	Not recovered	02/06/96	End of study
10/06/95 GH 07	J/_ #14	--	8	GH 07	10/12/95	Collar removed
10/09/95	J/_	--	4	GH 15	10/24/95	Collar

[1]A = Adult J = Juvenile

GH 07	#15					chewed off
MEANS	8A 7J	0.9214	29.5			

[1]A = Adult J = Juvenile

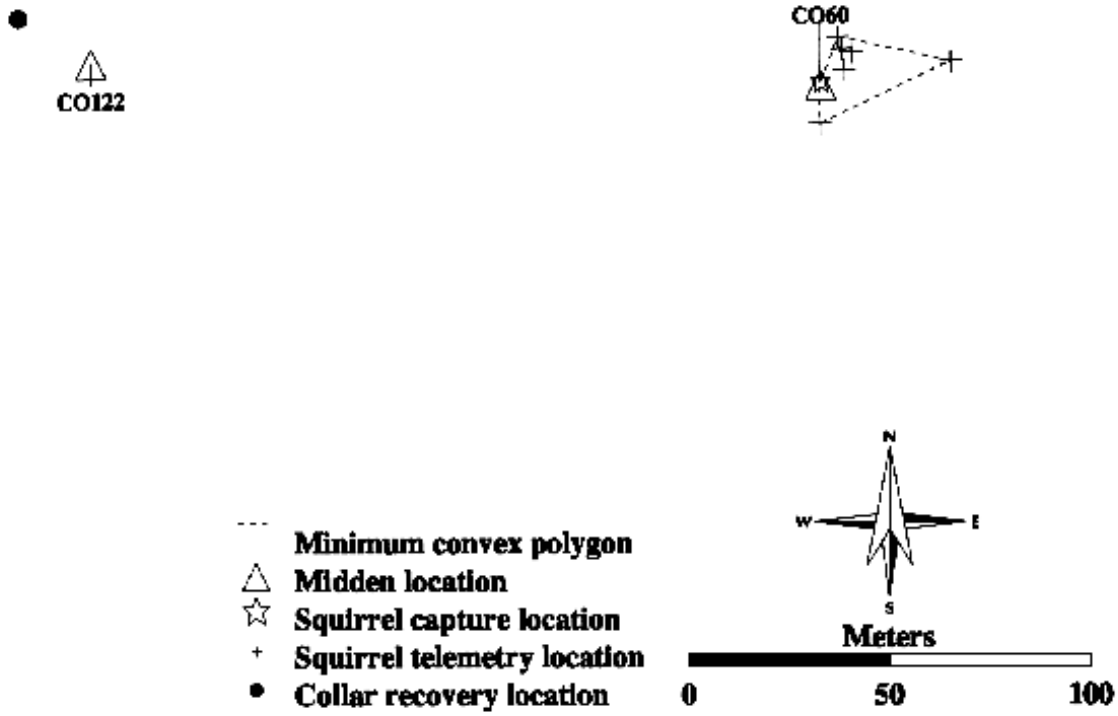

Figure 1. Estimated home range of squirrel number 1.

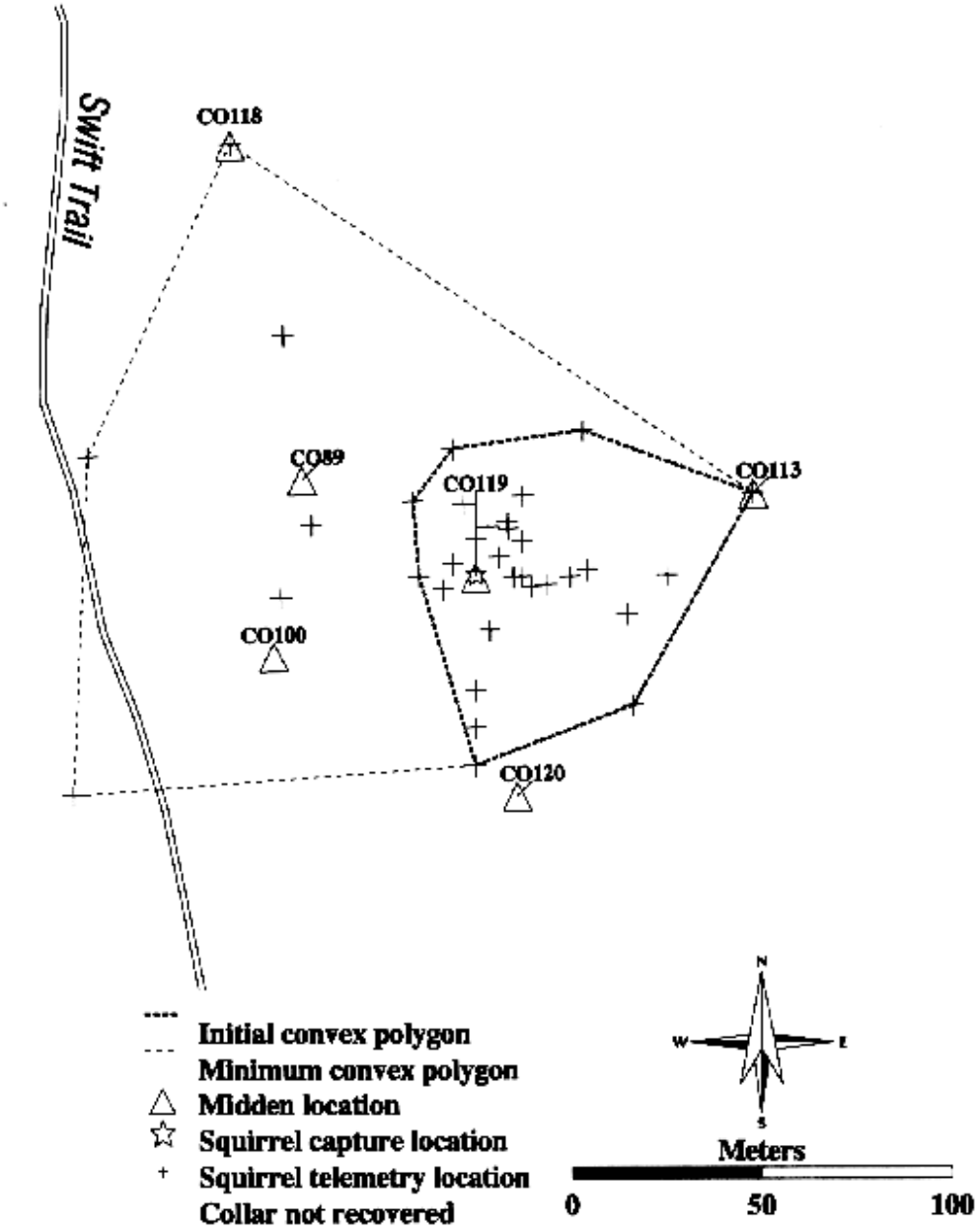

Figure 2. Estimated home range of squirrel number 2.

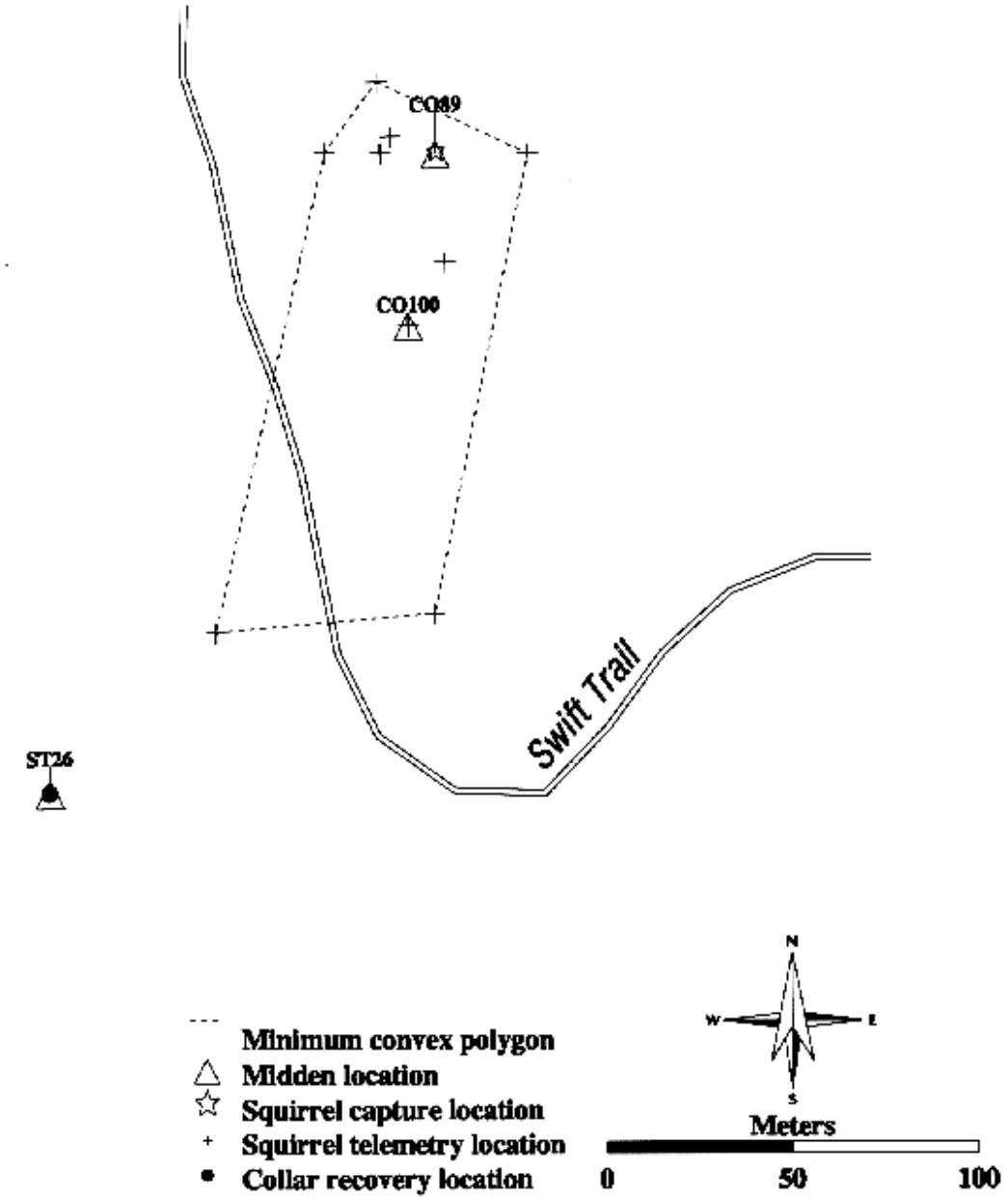

Figure 3. Estimated home range of squirrel number 5.

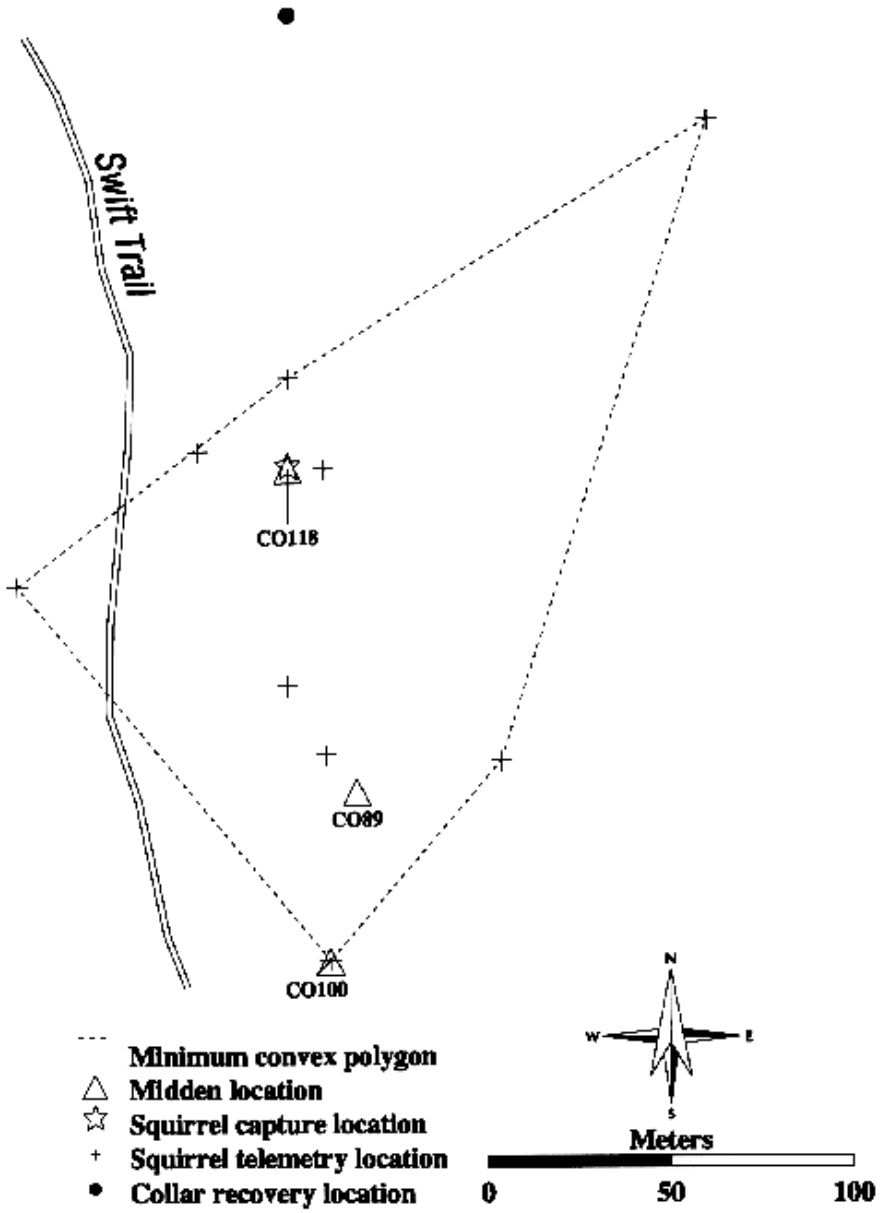

Figure 4. Estimated home range of squirrel number 6.

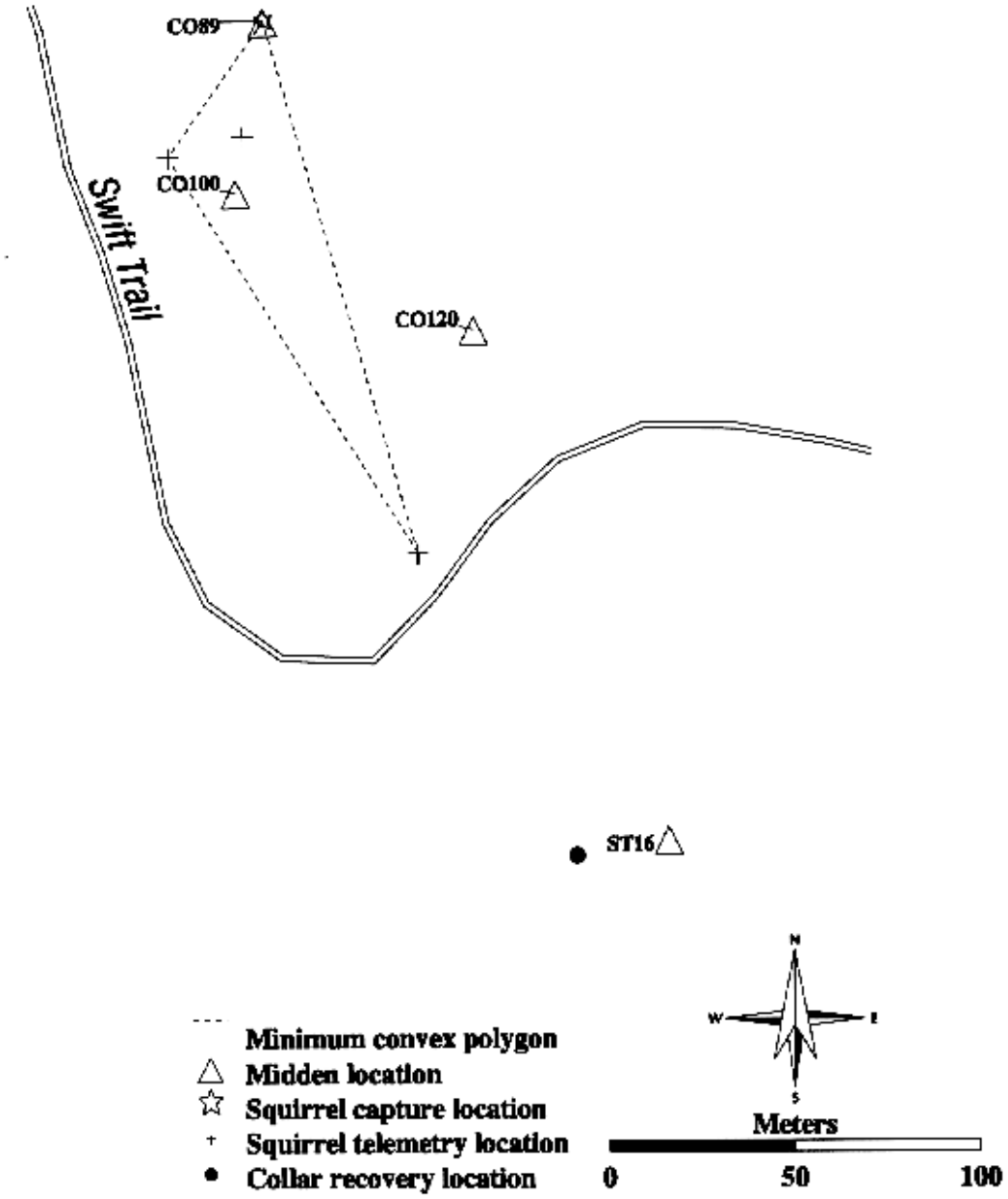

Figure 5. Estimated home range of squirrel number 4.

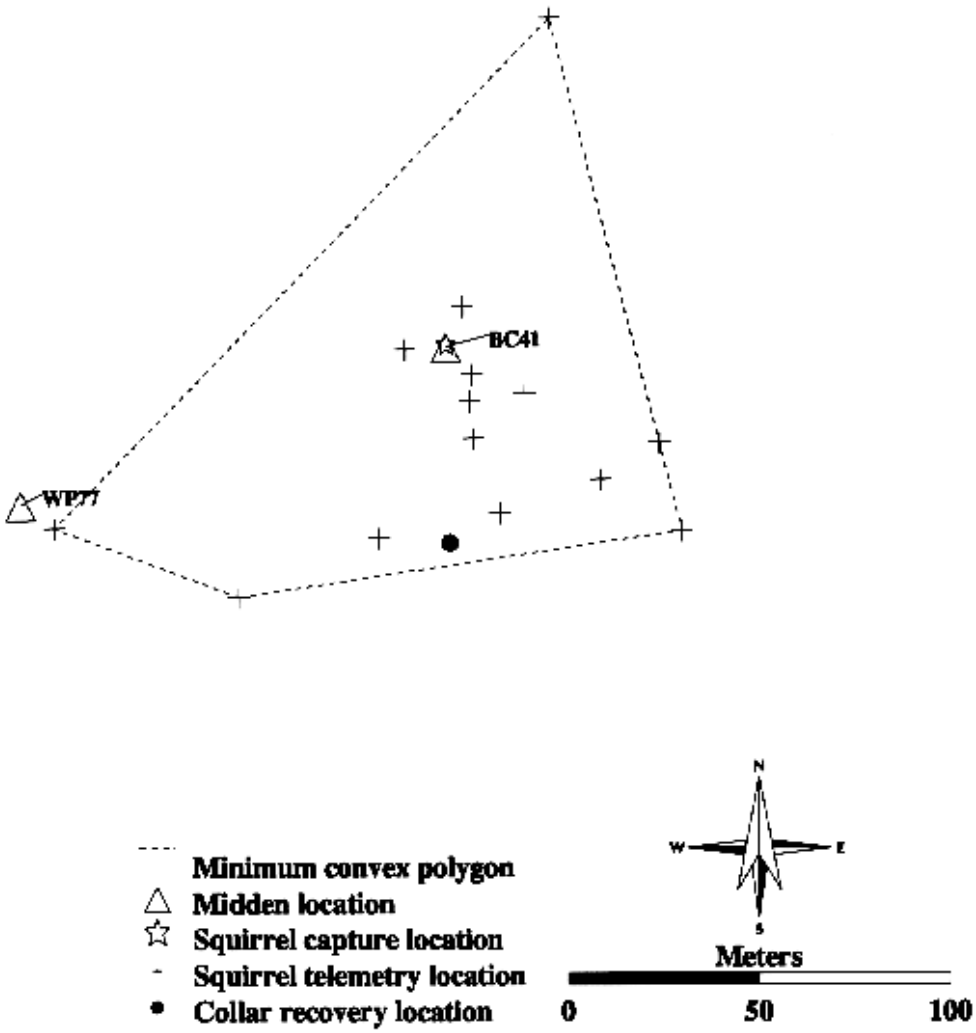

Figure 6. Estimated home range of squirrel number 9.

Squirrel number 3 also had multiple unoccupied middens within its home range (Fig. 7). None of the seven middens appeared to be the resident midden until the squirrel was observed caching cones at midden CO 116 on September 28, 1995. Even after residency was established, the squirrel continued to occasionally use middens CO 70 and CO 115 as feeding areas. This individual was never observed defending the midden at which it was captured (CO 114).

One squirrel, number 7, was collared at the same midden as number 1 after its death, but the home ranges did not follow the same boundaries (Fig. 8).

DISPERSAL

Dispersal results are considered tentative. Mortality from predation affected this project significantly, as did removal of collars by other MGRSs, and we concluded that only two juveniles could be used for calculations.

The two juveniles we were able to successfully monitor for a period of four months both dispersed to areas not adjacent to their natal middens. No adult females were still present at these natal middens. The juvenile female, number 13, selected an unoccupied midden 300 m from the natal site (Fig. 9) while a sibling, squirrel number 14, appeared to be setting up residency at the natal midden. Unfortunately, the collar of number 14 had to be removed due to slippage before this could be confirmed. Another juvenile, number 8, dispersed 1885 m and settled in an area adjacent to, but not including, an established occupied midden (Fig. 10). No squirrels were observed residing at their natal middens.

SURVIVAL RATES

Survival rates could not be determined for our study as a whole, since factors other than predation also influenced the results. The term survival rate is therefore conservatively used when calculating the amount of time a collared squirrel was known to be alive, with an ending time when the individual was preyed upon, its collar was chewed off, or the study ended.

The mean number of days juveniles survived was 48.8 days, while the mean number of days adults survived was 119.1 days. In 1994, predation on collared MGRSs was very high. Four radio collared squirrels were preyed upon before October 28, 1994. Evidence such as beak marks on the collars leads to the conclusion that raptors were the predators. Another squirrel's collar was recovered from under snow on April 26, 1995, and cause of death could not be determined. Two collars were not recovered.

From the 1995 trapping season, four collars on three squirrels were chewed off by December 6, one trap mortality occurred on September 13, one collar was recovered on October 7 after the squirrel was apparently preyed upon, and one collar was removed on October 12 due to slippage. Two collars were not recovered.

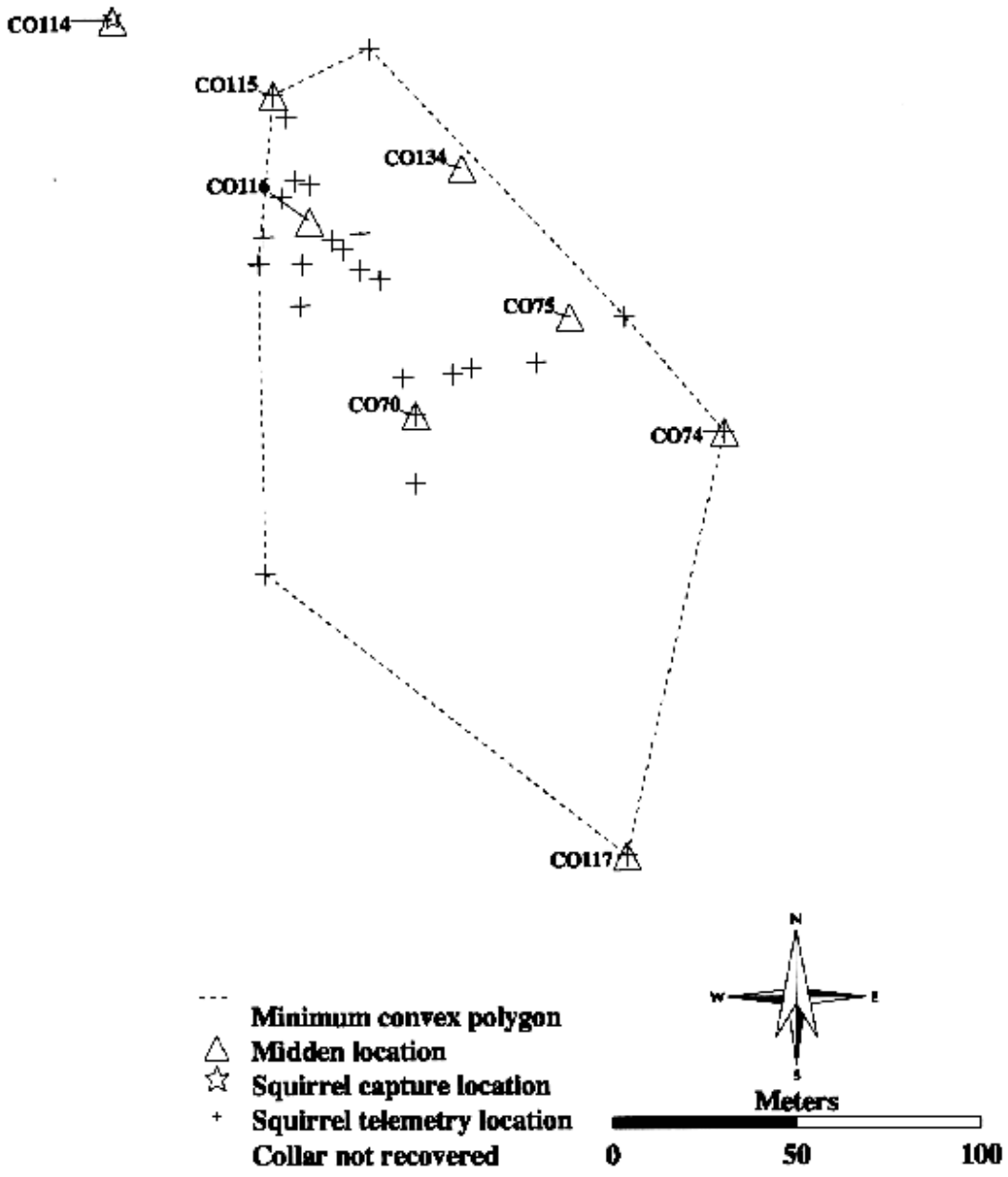

Figure 7. Estimated home range of squirrel number 3.

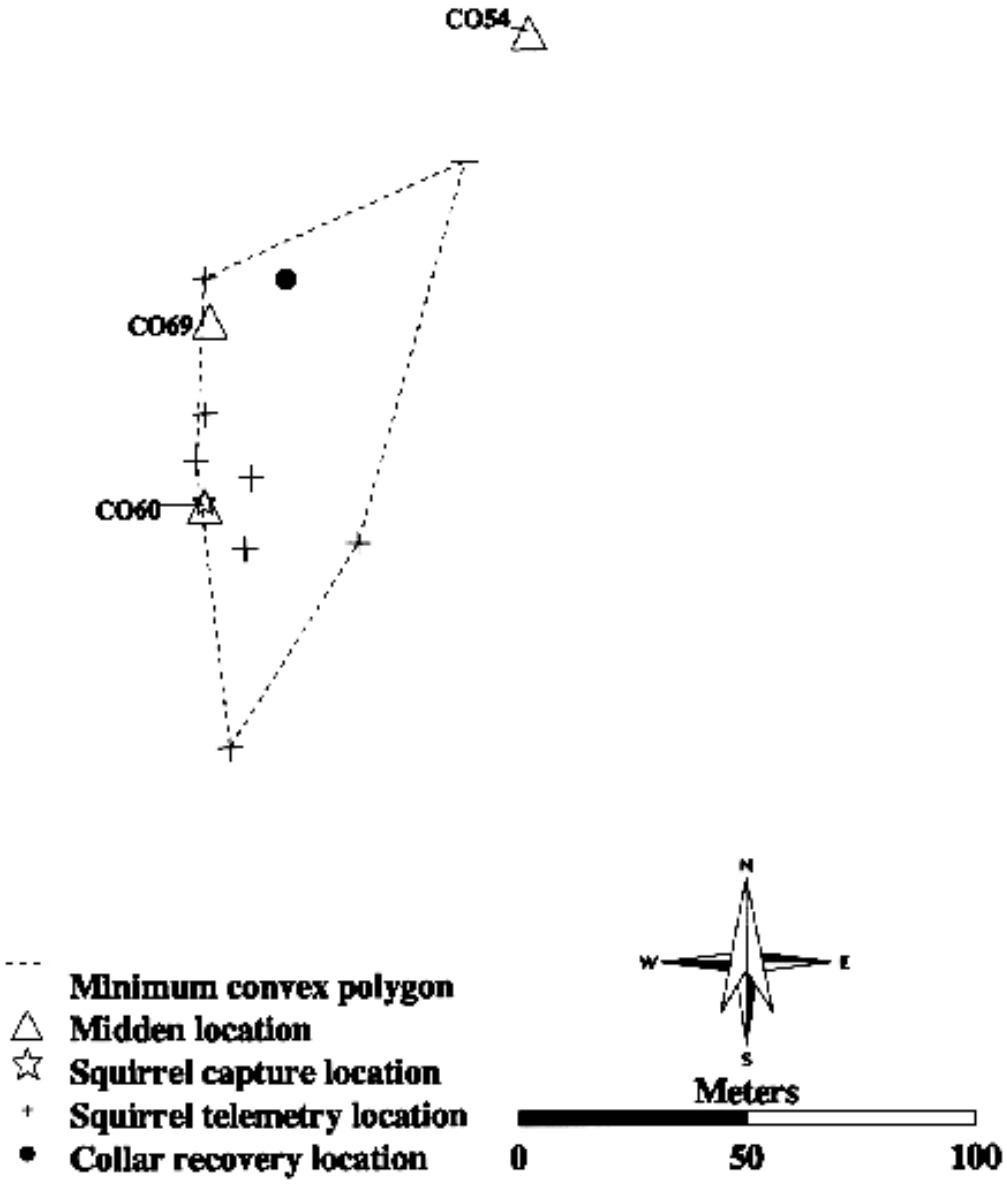

Figure 8. Estimated home range of squirrel number 7.

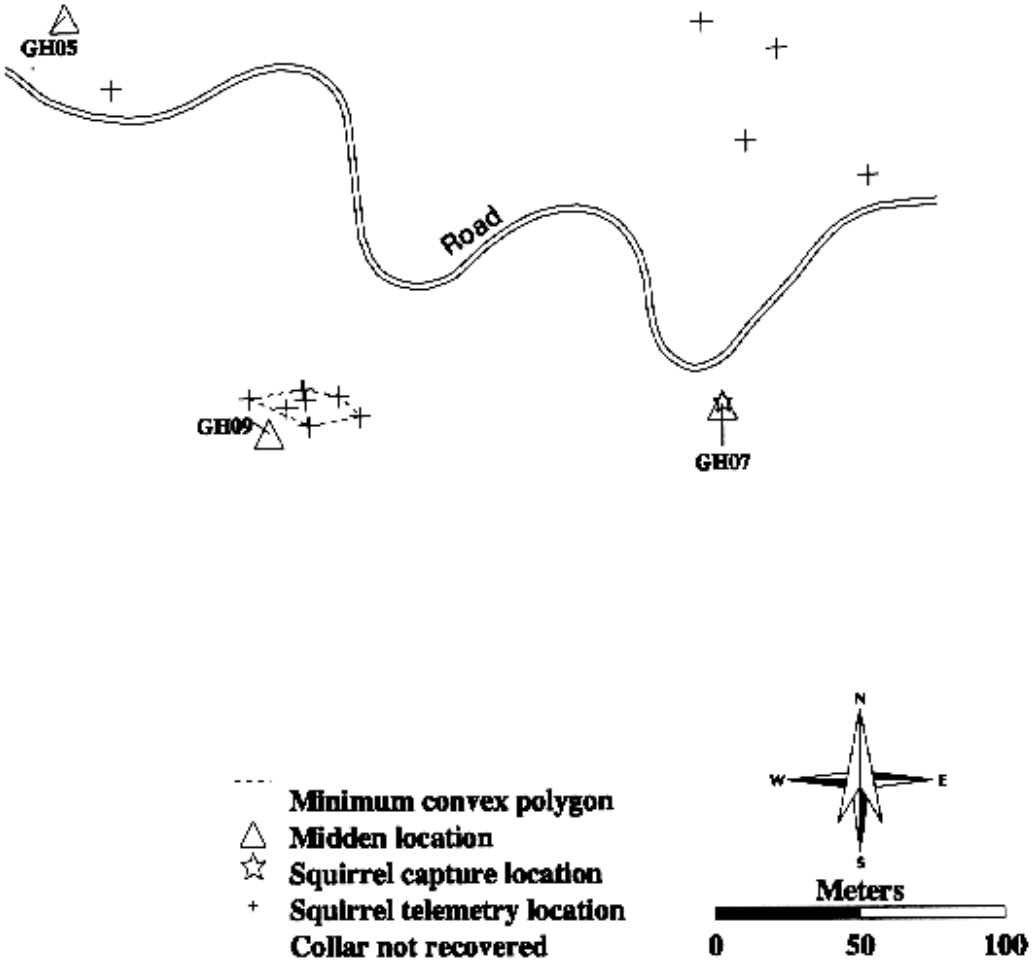

Figure 9. Estimated home range of squirrel number 13.

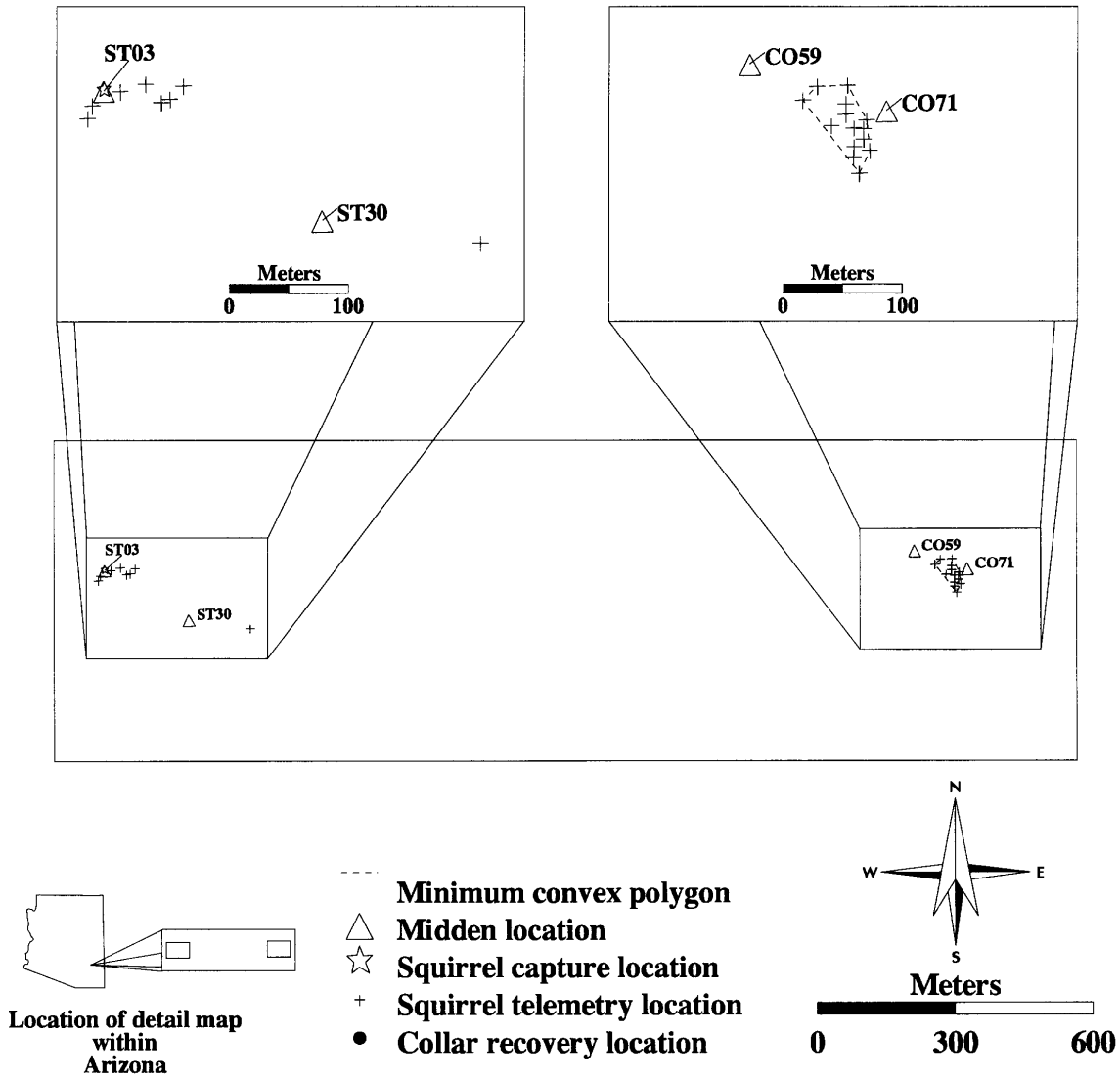

Figure 10. Estimated home range of squirrel number 8.

Overall, four collars were not recovered. From the 1994 field season, one squirrel's battery expired when expected and the squirrel disappeared. After a year the squirrel showed up still wearing the collar then disappeared. The other collar might have been chewed off inside a winter nest, or the squirrel might have died within the nest. From the 1995 field season, one squirrel possibly chewed off its antenna, thereby rendering the collar inaudible with the telemetry unit, and the fourth collar was left on due to the conclusion of the study.
Several of the squirrels from 1995 did not have enough data to make mapping feasible. These squirrels were numbers 11, 12, 14, and 15.

DISCUSSION

HOME RANGE

The mean home range size for MGRSs in this study was less than calculated by Krausman and Smith (1990), but was more than those reported for other populations of red squirrels (Smith 1968, Kemp and Keith 1970, Zirul and Fuller 1970, Gurnell 1984, Price et al. 1986, Wells 1987, Boutin and Schweiger 1988, Klenner 1991, Larsen and Boutin 1994). Locational observations also brought to light two behaviors of MGRSs that need to be explored further.

Other populations of red squirrels (Smith 1968, Kemp and Keith 1970, Price et al. 1986), due to their nearly 100 percent occupancy rate, at times may not have enough unoccupied home ranges to accommodate all squirrels, and vacant middens are filled in a short period of time with the same perimeter boundaries (Smith 1968, Price et al. 1986). Removal of residents during the dispersal time resulted in home ranges that did not alter from resident to resident (Price et al. 1986), because competition was severe. If residents and incoming vagrants were removed before dispersal (therefore lack of competition), then resident squirrels did expand their home ranges to include the newly vacated areas (Boutin and Schweiger 1988). Mount Graham, within the study areas, has about a 50 percent occupancy rate of established middens (Young 1994, 1995, 1996), and competition for unoccupied middens is therefore not as severe. The squirrel (number 7) that moved onto the home range of a previously collared squirrel did not stay within the same boundaries as the original resident, but occupied a home range over eleven times as large. The squirrel (number 2) that expanded its home range twice after the death of neighbors may not have had to compete with any other squirrels to do so. Had the neighbors not been removed, it follows that the initial home range would have been adequate to see the squirrel through the winter. The fact that cones had already been cached at these middens was most likely a motivating factor for expansion.

All but one squirrel from this study were observed at one time or another in the vicinity of other middens, both occupied and unoccupied. Other studies observed the same behavior (Boutin and Schweiger 1988, Young 1994, Young 1995). Both expanding home range to include unoccupied middens and occasional forays into unoccupied middens can mislead observers into believing these middens are occupied by separate squirrels. Only with squirrels that have identifying markings can multiple midden use be accurately determined.

DISPERSAL DISTANCES AND MIDDEN SELECTION

The 584 m mean dispersal distance (range from 300 to 1885 m) during a medium cone crop year (McCluhan 1995) was quite different when compared to other studies. Larsen and Boutin (1994) calculated a mean dispersal distance of 88.6 m that ranges from 0 to 323 m, and nearly half of 73 squirrels settled on or adjacent to the natal site. Wells (1987) observed juveniles settling, in relation to the mother, on adjacent or overlapping home ranges. Kemp and Keith (1970) noted cone crop abundance was a major factor in where juveniles settled. If the crop was good, young typically settled near the perimeter of the mother's home range. If the crop was poor, juveniles settled as much as 1.6 km away while the mother remained at the natal midden.

We were able to monitor dispersal activities for only two squirrels (numbers 8 and 13). Both survived and established home ranges into the following year. Squirrel number 8 traveled a long distance (1885 m) from a less populated area to an overly saturated area. As a consequence of severe competition, it did not obtain a traditional midden site. Instead, it started caching cones under logs outside the main area of the nearest midden, which was occupied by another squirrel. Up until the time of this writing the squirrel is still in the same location and even survived the Clark Peak fire as it swept through the area (P.J. Young pers. comm.).

Squirrel number 13 was trapped in a sparsely populated area. Immediately after collaring it left the natal midden, wandering and foraging for almost a month before finally settling on an established, unoccupied midden 300 m from the capture site.

DISPERSAL FREQUENCY OF ADULTS VERSUS JUVENILES

In only one instance were we successful in capturing both an adult female and a juvenile from the same family unit. Unfortunately, the juvenile was preyed upon a week after collaring and the female a month later. Of the six adult females collared in 1994, four remained on the natal midden, one never returned to the collaring site but was nomadic, and one was collared at the same midden as a previously collared female after it was preyed upon. Therefore, there was a 67% non-bequeathing rate.

In 1995, two juveniles were successful in establishing home ranges that were not adjacent to or overlapping with the natal area, even though no adult females remained at the natal middens. One collared adult female in a different area remained at the natal midden until its collar was chewed off, well past the dispersal season. Therefore, with the data we have, there was a 100 percent non-bequeathing rate. The mean for both years is 83.5 percent.

In comparison, Larsen and Boutin (1994) found that of 73 offspring establishing a home range, only eight gained complete control of their natal area. Five of those had mothers that were still alive. This translates into a 93 percent non-bequeathing rate.

The hypothesis that local competition, or lack thereof, determines whether offspring settle further away or remain close to their natal site was researched by Wauters et al. (1994), who showed that other factors, such as body weight, lifetime reproductive success and success of males to obtain a high dominance did not differ between residents by birth and those that immigrated in and settled.

There are trade-offs for both squirrels that disperse and those that remain on or near their natal range. By dispersing, a squirrel avoids inbreeding, and possibly escapes competition for resources, including mates (in the case of males), food, and suitable habitats. In contrast, those that remain are already familiar with the area and aware of the boundaries set by other squirrels and locations of the best resources (Wauters et al. 1994). Mortality is higher for those that disperse than for those that do not, but once a home range is established, dispersers that settled farther away have better overwinter survival (Larsen and Boutin 1994).

If the mother squirrel stays at the midden, the juveniles generally must disperse. Some studies found that part of the natal midden was given to young squirrels, usually the females (Brown 1984, Price et al. 1986, Wells 1987). Price (1992) noted bequeathal was related to whether a litter was early in the season or late. Late litters have a better chance of survival if the mother bequeaths, because there is limited time to set up or find a midden and the adult is more experienced. Also, juveniles are not able to defend a home range until they are 8-10 weeks old (Price 1992), and late litters might not have enough time after reaching that age to find, defend and store cones in a home range that is vacant. If the mother leaves, the juveniles can divide the midden or disperse (Brown 1984, Price et al. 1986, Smith 1968, Wells 1987). Early litters have more time to explore and set up residence elsewhere from the natal midden, so the mother tends to stay in the natal midden and the juveniles disperse (Price 1992). If the mother has expanded its home range it is more likely to bequeath part of the expanded area to its offspring than those squirrels that did not expand (Boutin and Schweiger 1988).

Two adult females had collars chewed off after juveniles were no longer observed in the midden. Red squirrels have been known to continue associating with related squirrels, especially mothers and daughters, and even have shared winter nests (Wells 1987, Price 1992). Whether these juveniles remained in the area all winter can not be determined. One collar was chewed off in December, way past the best cone storing time, so the squirrel that did it must have had a midden with stored cones nearby in order to survive the winter. The mother remained at the natal midden until data could no longer be obtained.

SURVIVAL RATES

Adults survived almost two and a half times as long as juveniles. Even with our small sample size, these survival rates are very close to results from other studies (Halvorson and Engeman 1983, Brown 1984, Wells 1987, Larsen and Boutin 1994).

The high squirrel density where trapping took place in 1994 may make hunting more cost-efficient for predators (Newton 1979, Widen 1989, Perrins et al. 1991). Several red-tailed hawks (*Buteo*

jamaicensis) and goshawks (*Accipiter gentilis*) were observed flying overhead in the squirrel monitoring area, and an attempted attack on one squirrel was documented. Similar to other studies (Smith 1968, Larsen and Boutin 1994), we found raptor predation to be the main cause of mortality. After the squirrels were preyed upon, two collar retrieval sites contained raptor mutes. Damage to all the collars was characteristic of raptor beak marks (R.L. Glinski pers. comm.).

Dispersing juveniles are more susceptible to predation, due to exploration of unknown areas with unfamiliar escape routes. They also are likely preoccupied with avoiding resident squirrels (Metzgar 1967). In most cases, juvenile males are the first to disperse, and they disperse further distances (Wells 1987). This may explain why squirrel number 4 was preyed upon during pre-dispersal forays.

In the case of lactating and postweaning females, the stress of greater movements to find enough food to feed themselves and their young plays an important part in their vulnerability to predation (Fancy 1981). Females do not cache cones until the juveniles are no longer on the home range (Smith 1968). If the season is getting late, as in our 1994 study, constant caching is a priority to prepare for winter, with possible foraging into unknown neighboring home ranges. Again, avoidance of home range holders could preoccupy a squirrel and make it more vulnerable to predation. All three of the collared adult females preyed upon in 1994 were postweaning.

Raptors were also observed quite often during 1995, both in densely and sparsely populated areas. However, predation of collared squirrels in 1995 was not as big a factor as in 1994. Juveniles and adults that nest together tend to participate in social grooming and play (Prescott and Ferron 1978), which can lead to chewing off collars (Beal 1967, Madden and Giacalone-Madden 1982, Thiel and Fritts 1983, Wells 1987). This is what we presume occurred for the majority of the collared squirrels in 1995. Collared squirrels most likely did not die immediately after having their collars chewed off by conspecifics, but we could not determine if and when mortality occurred. Only one squirrel was possibly preyed upon, but evidence as in 1994 was not present at the collar recovery site.

RECOMMENDATIONS

1. Future studies that may involve or be based upon capture of MGRSs should first investigate alternative capture methods and seek approval from the proper authorities to use such methods. Traditional trapping methods require tremendous amounts of time for each capture and are less efficient in capturing dispersing juveniles.

2. It is essential to develop a collar that minimizes or prevents removal by other squirrels. It should also be expandable to allow proper tightening for juveniles, but not restrict growth or normal activities.

3. Sufficient personnel need to be available for two crews: one crew to trap and radio-collared squirrels, and a second crew to locate and track radio-collared squirrels. Trapping and tracking must be done independently and simultaneously to maximize data collection and

efficiently use available collared squirrels.

4. Two behaviors that were observed, multiple squirrels using one midden and one squirrel using multiple middens, should be further investigated on Mount Graham. How frequently these behaviors occur and what impact they could have on, or bias they could inject into, population estimates are important questions that need to be answered.

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PERSONAL COMMUNICATIONS

Glinski, R.L. Arizona Game and Fish Department, 2221 West Greenway Road, Phoenix, AZ 85023.

Young, P.J. University of Arizona Mount Graham Red Squirrel Monitoring Program Supervisor, 220 BioSciences West, Tucson, AZ 85721.